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ABSTRACT

During the past century, most research addressing the legibility of text in print has used adult subjects. The study reported in this paper investigated differences in reading rate and comprehension scores of eighth grade students reading from paper copy or computer screen. Three hundred eighth grade students in computer literacy classes were randomly assigned to 10 treatment groups. Subjects were timed as they completed a cloze reading passage, decided which words were missing, and wrote those words on an answer sheet. This time was used as the reading rate. Passages were subsequently scored, and the scores were used as the comprehension rate. Subjects all read the same passage, but the passage was presented in one of 10 different text presentation modes involving variation in line length, background and foreground color, and contrast ratio in order to facilitate comparisons among the treatment groups. Two one-way ANCOVAs were used to analyze the data; one ANCOVA analyzed reading rate while the other analyzed the comprehension scores. The finding of no statistically significant differences in reading rate for any of the 10 groups conflicts with most of the findings from adult reading rate research, suggesting that reading level might be a factor affecting reading rate from electronic screens or paper. The finding of no difference in comprehension was consistent with previous studies. Thus, the ability of adults or eighth grade students to comprehend text does not appear to be impaired by the decreased legibility of computer screens. (27 references) (Author/GL)

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Title:

Paper Versus CRT - Are Reading Rate and Comprehension Affected?

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ABSTRACT

In the past century, much research has addressed the legibility of text in print. Sanford (1888), Griffing and Franz (1896) and Tinker (1963) have contributed to this body of knowledge. Studies were performed to determine the best length of line, color, and line spacing, etc. More recently, researchers have found that reading rate is adversely affected by the legibility of the electronic screen text. Most legibility studies used adult subjects.

The only reading from a computer screen studies involving junior high school students were by Feldmann and Fish (1987, 1988). The major focus of the study, was to determine if reading from the computer screen affected junior high school students' comprehension. Additionally, the study questioned whether reading rates were affected by the legibility of electronic screen text.

The present study investigated differences in reading rate and comprehension scores of eighth grade students on a cloze reading exercise involving the reading of a cloze passage from ten different modes text of presentation. The study was designed to compare reading rate and comprehension scores of junior high students reading from paper copy or computer screen. In addition, the study was designed to determine optimal electronic screen text presentation modes, involving line length, background and foreground color, and contrast ratio.

Two one-way ANCOVAs were used to analyze the data. One ANCOVA analyzed reading rate while the other analyzed the comprehension scores. The ANCOVA results indicated that there were no statistically significant differences in reading rate or comprehension score for any of the ten groups.

The findings of no differences in reading speed from electronic screens to paper conflicts with most of the findings on adult reading rate research (Gould & Grischkowsky, 1984, 1986; Hathaway, 1984). Reasons accounting for the difference in findings may be: (a) the reading of the adult subjects was superior to the eighth grade students; (b) the nature of the reading materials, proofreading as opposed to a cloze passage; and (c) the focus on groups of students rather than the individualized treatment of adults. This would suggest that reading level might be a factor affecting reading rate from electronic screens or paper.

The finding of no difference in comprehension was consistent with previous studies. Thus, the ability of adults or eighth grade students, to comprehend text does not appear to be impaired by the

decreased legibility of computer screens. Although the reading rate of adults seems to be effected by the legibility of computer screens, eighth grade students' reading rates do not appear to be adversely affected.

Paper Versus CRT - Are Reading Rate and Comprehension Affected?

Computers and electronic screens have become integral parts of American society. Office workers, engineers, scientists, designers, writers, accountants, and many others spend long hours in front of electronic screens. Often, the amount of text presented on the screen is considerable.

Student computer usage in schools has increased rapidly. There are approximately 52 thousand computers, for instructional purposes, in approximately 48 percent of the public school districts (Becker, 1986; Niman, 1987). Many states now require students to take computer literacy classes. Because of the great influx of computers into schools, the time has come to assess the impact of the electronic screen on reading performance in a school setting.

Reading Performance

There is considerable evidence that electronic screens negatively impact reading performance when presenting text. Adults read more slowly from electronic screens (Gould, Alfaro, Barnes, Finn, Grischkowsky, & Minuto, 1987; Gould, Alfaro, Finn, Haupt, & Minuto, 1987; Gould & Grischkowsky, 1984, 1986; Hansen, Doring, & Whitlock, 1978; Hathaway, 1984; Kruk & Muter, 1984; Muter, Latremouille, Treurniet, & Beam, 1982). A few studies (Gould & Grischkousky, 1984, 1986; Muter et al., 1982) have indicated that reading rate decreased by as much as 20 to 30 percent when the computer-based electronic screen was the mode of text presentation.

Text Legibility

Text legibility research defines those features that affect electronic screen text legibility. According to Tinker (1963), a foremost scholar in printed text legibility, reading speed is critically dependent upon text legibility. Legibility, according to Tinker (1963, p. 8),

> ...deals with the coordination of those typographical factors inherent in letters and other symbols, words, and connected textual material which affect ease and speed of reading.

The factors associated with legibility include: the size of the print, the shape of the font, the illumination of the reading environment, the color and quality of the paper, and the distance between letters and between lines of print. Daniel (1985, p. 4) in referring to electronic screens stated, "the term 'legibility' denotes how specific physical characteristics of a display effect

[sic] visual fatigue, reading speed, and ultimately comprehension".

Studies of printed text legibility date back to Sanford (1888) and Griffing and Franz (1896). Huey (1968) summarized many text legibility studies and made recommendations about the optimum text presentation. The conclusions from Huey (1968) included: (a) the type should be no smaller than 1.5 mm or 6 points, (b) the optimal line length should be between 90 and 100 mm or about 60 characters per line, (c) the best color paper is white, and (d) the use of double spaced text or additional leading, that is more space between lines of print improves legibility. Tinker (1963) also found that the curvature of printed material, like that found in books with narrow "gutters", reduced reading speed.

Finally, Tinker (1963) investigated color combinations of print and paper. Tinker (1963) observed that black print on a white background, "yielded the most rapid reading" (p. 146). But, other color combinations were almost as effective: green on white, blue on white, and black on yellow. All other color combinations retarded speed of reading considerably.

Computer Screen Legibility

During the 1970s and 1980s, researchers investigated electronic screen legibility. Hoover (1977) compared reading performance with single and double spaced computer text. No statistically significant differences were found in reading rate although the subjects indicated that they had more trouble reading single spaced text (Hoover, 1977).

Kruk and Muter (1984) performed a series of three experiments to determine if it was feasible to read continuous text from an electronic screen. They concluded that it was feasible, but that reading speed was slowed by approximately 25 percent. They later concluded that this speed deficit could be decreased to 10.9 percent through the use of double spacing.

Other studies investigated reading rate using printed text and computer screen text. Hansen et al. (1978) had college students take a reading test on computer-based electronic screens and on paper. They found that students read more slowly on computer screens. Kak (1981) performed a similar study with a standardized, timed reading test. Kak's results indicated no statistically significant differences in reading scores when only completed parts of the test were graded. However, a four percent slower reading speed was reported for students taking the test on computer. Kak (1981) concluded "that legibility criteria may be excessively strict when applied to tasks involving reading of connected prose text" (p. 139).

Switchenko (1984) conducted a study involving adult subjects in a comprehension reading task. Subjects read two short articles which differed in degree of difficulty. Subject then answered comprehension questions. Switchenko found no significant differences in reading speed or comprehension scores from computer or paper. Switchenko (1984) argued that studies which found a difference in reading speed did not have adequate and proper experimental controls. Gould et al. (1987) concluded that adults could read as fast from a computer screen as they could read from paper. In the experiment, the fonts appeared similar in the two media. An extremely high resolution computer displays with black font on a white background was used. Thus, there is some controversy whether or not reading speed is decreased on a computer screen. An important note that needs to be made is that all of these studies used adults. To this point, there are only two studies (Feldmann & Fish, 1987a, 1987b) involving school aged children assessing reading rate and comprehension differences with paper and computer screens.

Statement of the Problem

A survey of available literature on electronic screen legibility uncovered only one related study involving junior high age students (Feldmann & Fish, 1987b). The students in the study were high ability eighth grade students and no statistically significant difference in reading comprehension was found between paper and computer-based electronic screen media. Other electronic screen legibility studies were generally conducted in the workplace with small samples of convenient adult subjects.

Other questions also need to be addressed. If indeed, junior high students do read more slowly from electronic screens as adults seem to, are there easily controlled factors which might improve the legibility of print on electronic screens?

The present study investigated if there were differences in reading rate scores of eighth grade junior high students on a cloze reading comprehension task involving the reading of text from several different modes of presentation. The following modes of presentation were studies:

1. An electronic screen with white text on black background utilizing a line length of 60 characters.
2. An electronic screen with white text on a black background utilizing a line length of 80 characters.
3. An electronic screen with black text on white background utilizing a line length of 60 characters.
4. An electronic screen with black text on white background utilizing a line length of 80 characters.

5. An electronic screen with black text on a light blue background utilizing a line length of 60 characters.
6. An electronic screen with black text on a light blue background utilizing a line length of 80 characters.
7. An electronic screen with white text on a light blue background utilizing a line length of 60 characters.
8. An electronic screen with white text on a light blue background utilizing a line length of 80 characters.
9. White paper with black IBM PC Junior matching font printed on a dot matrix printer with a line length of 60 characters.
10. White paper with black Courier 10 font printed on a laser printer with a line length of 60 characters.

The two research questions addressed in this study were:
1. Is there a difference in eighth grade students' reading rate on a reading comprehension task among groups performing the task using several different modes of presentation?

2. Is there a difference in eighth grade student's comprehension score on the reading comprehension task among groups performing the task using several different modes of presentation?

Method

Three hundred junior high school students in computer literacy classes, in seven schools from a large suburban school system, were involved in this study. The subjects were randomly placed into one of 10 treatment groups. The subjects completed a cloze reading passage. The first and last sentences of the passage were left intact, but every fifth word in the main body of the passage was deleted. The passage had fifty missing words. The students read the passage, decided which words were missing, and wrote these words on an answer sheet. The time, in minutes and seconds, taken to complete the exercise was measured by the investigator using a stop watch. The time to complete the passage was used as the subject's reading rate. The passages were subsequently scored, and this score was used as the subject's comprehension measure. Subjects all read the same passage, but the passage was presented in one of the 10 different text presentation modes. This design allowed comparisons to be made among the means of the various treatment groups.

In order to allow the subjects to become familiar with the cloze procedure, subjects participated in a 20 minute practice session one day before the data collection. The practice session also enabled the subjects to practice using the arrow keys on the computer to scroll text forward and backward on the screen. Actual collection of data took one class period. Administration of the cloze passage took approximately 30 to 35 minutes. Collection of

materials took approximately 5 minutes with no more than 45 to 50 minutes was needed to collect the data. Class periods in the schools participating in the study were 55 minutes in length.

The students were told that their reading would be timed, but that reading time was not as important as being accurate. Students were asked to raise their hand when they completed the exercise. A stop watch was used to measure the time it took students to complete the cloze passage. When all students had completed the exercise, all materials were collected.

Instrumentation

The De Santi Cloze Reading Inventory was used as the dependent variable. The cloze procedure may be used to determine if students are able to comprehend certain material. Three levels are used in traditional measures of comprehension for cloze passages: independent, instructional, and frustration. Fifty responses are possible in the passage and the number of correct responses is multiplied by .02 to derive a percentage.

"The inventory was field tested 3,456 times with a total of 864 students drawn from two school systems (De Santi, Casbergue, & Sullivan, 1986, p. 131). The correlated concurrent and predictive validity for eighth grade cloze passages with CTBS total reading scores was found to be statistically significant at the .001 level.

The inventory has single-rater and inter-rater reliability. De Santi and Sullivan (1985) determined single-rater reliability; the mean reliability of the Traditional Comprehension interpretation value was determined to be .96. This was also the mean value for the inter-rater reliability (De Santi & Sullivan, 1985).

For the purposes of this study, The De Santi Cloze Reading Inventory was converted to the eight different computer presentation modes. Additionally, two different paper presentations modes were created. The first paper version (group 9) was created using the ChiWriter (1988) software package to create a font similar to the font used on the IBM PC Junior computer screen. The second paper version (group 10) was printed on a laser printer with Courier 10 font. These modifications were made to place better controls on the presentation modes.

Results

The results of the two research questions are presented.

1. Is there a difference in eighth grade students' reading rate on a reading comprehension task among groups performing the task using several different modes of presentation?

To test this first hypotheses, a balanced one way Analysis of Covariance (ANCOVA) statistical procedure was performed using SPSSPC. The reading rate of subjects on the cloze reading task was the dependent variable while the covariate was the normal curve equivalence (NCE) score on the Total Reading subtest of the CTBS. Table 1 presents a summary of descriptive statistics for the CTBS covariate scores. The highest score for the sample test was 99 and the lowest score was 3.

INSERT TABLE 1 ABOUT HERE

Subjects were randomly assigned by the use of a random number table to 10 text presentation groups. The mean reading rate for each group was determined. Table 2 presents the mean and standard deviation for the reading rate of the 10 groups.

INSERT TABLE 2 ABOUT HERE

No statistically significant differences were found at the .05 level in the omnibus hypothesis among the means. Additionally, the effect size was low (4.5%), thus the results were also not educationally significant. Table 3 presents the ANCOVA summary table for reading rate. The null hypothesis was not rejected; therefore, no post hoc tests were performed. This finding contradicts most research studies (Granaas, McKay, Laham, Hurt, & Juola, 1984; Heppner, Anderson, Farstrup, & Weiderman, 1985).

INSERT TABLE 3 ABOUT HERE

When performing a cloze reading exercise, the reading rate of eighth grade students was not statistically or educationally significant when reading from paper or computer. Although no statistical differences were found with the ANCOVAs, students with independent level reading ability did read 27 percent slower from electronic screens than paper.

2. Is there a difference in eighth grade student's comprehension score on the reading comprehension task among groups performing the task using several different modes of presentation?

To test the second null hypothesis, a balanced one way ANCOVA statistical procedure was performed using the comprehension of subjects on the cloze reading task as the dependent variable. The covariate was the normal curve equivalence score (NCE) on the Total Reading subtest of the CTBS. A mean comprehension score was determined for each group. Table 2 presents the descriptive statistics for the comprehension scores.

No statistically significant differences were found among the means on the omnibus hypothesis. Table 4 presents the ANCOVA summary table for comprehension scores. The null hypothesis was not rejected and thus, no post hoc tests were performed.

Students' comprehension scores did not appear to differ for any of the groups tested. This finding was in agreement with the vast majority of previous studies which tested comprehension in various text modes (Feldmann & Fish, 1987a, 1987b, 1988; Gould et al., 1987; Gould & Grischkowsky, 1984, 1986; Kruk & Muter, 1984; Kak, 1981; Switchenko, 1984).

INSERT TABLE 4 ABOUT HERE

Conclusions

The findings of no differences in reading speed from electronic screens to paper conflicts with most of the findings on adult reading rate research (Gould et al., 1987; Gould et al., 1987; Gould & Grischkowsky, 1984, 1986; Hansen et al., 1978; Hathaway, 1984; Kruk & Muter, 1984). Reasons accounting for the difference in findings may be: (a) the reading of the adult subjects was superior to the eighth grade students; (b) the nature of the reading materials, proofreading as opposed to a cloze passage; and (c) the focus on groups of students rather than the individualized treatment of the adults. This would suggest that reading level might be a factor affecting reading rate from electronic screens or paper.

The finding of no difference in comprehension was consistent with previous studies. Thus, the ability to comprehend text is not necessarily a function of legibility but reading level. The reading rate is affected by legibility. Thus, a reader would reduce his reading rate in order to maintain comprehension.

Summary

There was no statistically significant difference in eighth grade students reading from electronic screen or paper. The length of lines or the medium seemed to make no difference. Thus, for a 30 minute reading task, the medium did not make a marked difference in either the reading rate or comprehension.

More research needs to be performed with school aged children to better identify if different ability groups of students are more or less affected by the presentation mode of text. Research should also be performed to investigate if the reading rate and/or comprehension would deteriorate given longer reading spans. Finally, other computers besides the IBM PC Junior should be used to determine if particular computers, and the generated font, affects reading rate and/or comprehension.

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Table 1

Means and Standard Deviations for CTBS Total Reading NCEs by Group

Group	Mean	SD
1	45.63	19.70
2	56.93	21.46
3	55.03	17.73
4	52.40	17.39
5	55.13	23.88
6	55.77	19.10
7	57.50	22.33
8	52.23	21.99
9	49.70	18.68
10	51.47	23.10
Total	54.08	20.48

Note. Each group contained an N of 30.

Table 2

Descriptive Statistics by Group on Reading Rate and Comprehension

	Reading Rate		Comprehension	
Group	Mean	SD	Mean	SD
1	12.28	3.84	49.80	9.00
2	14.10	5.57	50.40	8.43
3	13.36	4.34	50.87	8.55
4	13.13	3.30	45.53	7.25
5	12.90	3.66	50.73	7.17
6	12.16	4.03	48.53	9.67
7	13.86	5.30	48.47	9.77
8	13.02	3.68	46.80	12.29
9	11.96	4.05	50.13	8.40
10	12.78	6.05	48.13	10.53
Total	12.96	4.45	48.94	9.28

Note. Reading rate was measured in minutes.
Note. Each group contained an N of 30.

Table 3

ANCOVA Summary Table for the Effect of Text Mode Presentation on Reading Rate

Source	SS	df	MS	F	r^2
Covariate NCE	1154.78	1	1154.78	72.96	.195
Main Effect Group	205.31	9	22.81	1.44	.035
Residual	4574.27	289	15.83		

Table 4

ANCOVA Summary Table for the Effect of Text Mode Presentation on Comprehension

Source	SS	df	MS	F	r^2
Covariate NCE	10441.34	1	10441.34	207.37	.416
Main Effect Group	78.10	9	8.68	.17	.003
Residual	14551.49	289	50.35		